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The Study of Optical and Physical Properties of Natural Fogs

by

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(Presented by Academician O.U. Schmidt)

Translated by Esther Rabkin

ABSTRACT

The present paper gives the data of the observation of the polarization of light scattered by fog at different angles, and the absorption of light in natural fogs. The result of observation does not coincide with the theoretical data. In order to explain the discrepancy between observation and theory the hypothesis of the presence of submicroscopic drops in fogs is proposed.

1. Presentation of the problem

Since 1940 the institute of theoretical geophysics commenced a complex study of the optical properties of fogs in relation to their physical properties. The present paper describes the results of the first year of investigations.

During the last 12 to 15 years many investigations, amongst them a number of comprehensive, have been carried out on the study of fogs. After several authors have revealed that fogs are more transparent to infra-red rays than to visible rays, this problem became the centre of attention,

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since it assumed more practical importance. Therefore, it first of all became necessary to re-evaluate the possibilities of infra-red rays. They began to be looked upon as a universal medium.

However, such a conclusion had to be abandoned after a more careful all around investigation of the phenomena. In many cases the fog revealed poor transparency to infra-red rays. A great deal of factual material was collected, much of which was of a contradictory nature. The practical investigators were not always able to obtain from the physicist and geo-physicist clear descriptions on the procedure and methods for the utilization of infra-red rays in a fog and often were forced to act according to their own judgments and take risks. Due to certain complexities of the phenomena, such an empirical approach invariably leads to negative results in many cases. Therefore, there now exists an indifference, and sometimes even a skeptical attitude to the problem amongst the practical investigators, particularly when speaking of the possibilities for photography and photo elements in the region near to the infra-red. And although many countries are investigating the spectral transparency of fogs, the possibilities for practical utilization of infra-red rays in a fog are at the present even less definite than heretofore.

On the basis of a critical analysis of the published literature, we came to the conclusion that such an attitude to the problem does not correspond to the reality of the case.

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Although at present infra-red rays cannot be regarded as a universal medium in a fog which could be easily utilized, however this phenomena undoubtedly contains a number of possibilities, the utilization of which could be effective.

There are no fogs "generally"; a fog is a complex meteorological phenomena which is distinguished by a multiplicity of properties: one fog does not resemble another. The physicist and geo-physicist must give (but so far have not done so) a clear reply regarding the factors, which determine the actual transparency of each concrete fog, and must give convenient, simple methods, which would permit the obtaining of necessary information about fogs under practical conditions. Finally, it must be clearly stated what generally can and what cannot be expected from the adaptation of infra-red rays in fogs.

Having in mind several concrete methods for the solution of the stated problem, we undertook our investigation, even though in order to obtain final results a great deal (several years) of time will be required due to the complexity of the phenomena.

2. <u>The Methods of Measurement</u>

A successful solution for the present problem is possible only if a complex method for the investigation is adopted: it is essential to record simultaneously a number of properties of fog. This is necessary because of the complexity of fog as a physical phenomena.

The plan of the first year of work consisted in carrying out the following procedures:

(a) Photo-electric measurements of the transparency of a fog

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in the visible and infra-red section of the spectrum (from 450-1000 $m\mu$). For a better interpretation of the results we decided not to use light filters, in order to separate the essential sections of the spectrum, and included a monochromator in the installation.

The properties of photoelectric measurements are known, but under fog conditions it is necessary to take into account some of the shortcomings of this method. In orde. to obtain fairly detailed curves for the spectral transparency of a fog, it is necessary to take measurements in not less than 12-15 points of the spectrum. Since the measurements for the individual points must be made consecutively, a change in the properties of the fog during that time may result. This can be avoided by adopting photographic spectrophotometry.

(b) The Spectro-Photographic Method

A projector, containing a 100 watt lamp, was used as the source of light. At a distance of 275 M. from the projector a spectrograph was installed (Fig. 1). Two spectrographs were used simultaneously. One was a self-made spectrograph with a relative aperture f:4.5. The length of the spectrum from 400-600 $m\mu$ was 12 mm. the linear dispersion is 13 $m\mu$/mm. in the region 400-450 $m\mu$ and 43 $m\mu$/mm. in the region of 580 $m\mu$.

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[illegible] instrument was a Zeiss spectrograph with a direct vision [illegible]. It gave a spectrum of 50 mm. in length for the same interval of wave lengths, and had a linear dispersion of [illegible] mμ/mm. in the region 400-450 mμ, and [illegible] mμ/mm. in the region of [illegible]0 mμ.

The exposures of the spectra were made on Agfa plates of the Aeropan type. The transparency of the fog was determined after comparing the spectra obtained on one and the same plate in a fog and without fog. For the construction of the characteristic curves, we used a step wedge for the spectrograph slit (this step wedge is obtained by a cathodic dispersion of platinum onto a glass plate).

From this data we obtained the transparency curves for the region from 410-640 mμ.

(c) The Microphotography of Fog Drops.

In order to determine the radii of the drops, photos were taken by a camera connected with a microscope. The drops were deposited on a glass plate covered with a special grease. The details of these measurements were published in a paper by E. P. Smirnov (Izvestia of the Academy of Sciences, U.S.S.R. Geographic and Geophysic Section, No. 5. '41.).

(d) The Measurements of the Moisture in a Fog.

The procedure worked out for these measurements is still unsatisfactory. Smirnov utilized a somewhat better method than the method of the heated Assman psychrometer.

With the aid of a heater, installed on the psychrometer, the drops of the fog are evaporated; the increase in the quantity of water vapour determines the moisture content. The calculations are carried out by the differences in the readings of the two psychrometers, one heated and one unheated. For details of these measurements see the above mentioned paper by Smirnov.

(c) The Measurements of the Polarization of Light Scattered by the Fog Under Various Angles.

For these measurements we used a Cornu polarimeter. The measurements were made at angles of 60, 90 and 120°. These observations were made in order to explain the hypothesis of "sub microscopic" particles in a fog, which is described below.

The general position of the instruments during the time of measurements is shown on Fig. 1. A large working distance (275 M) was selected, in order to insure the study not only of the fogs but also of hazes having a visibility of 2-3 KM., since such hazes are a frequent phenomena in many geographic zones.

The measurements were carried out in natural fogs at points in flat country and far away from populated places. Work over large distances demands great sensitivity of the photo electric apparatus, particularly in the case when a monochromator with a narrow slit is used. Hence it was necessary to use amplifying apparatus of very precise design, the description of which is given below.

3. The Photo-Electric Apparatus

The photo electric apparatus was made by a somewhat different scheme than that of Dubridge (Fig. 2). Individual alkali accumulators of large capacity (30 A.H), connected in parallel, were used as the supply source for the cathodes of the tubes. Thus it was possible to have good stability without resorting to recharging. During the two months of the field work the self discharge of the accumulators was brought to a minimum by carefully insulating them from the walls of the metallic boxes. All the parts of the circuit, including the galvanometer, were carefully sealed. Tubes CI-2 operating on lowered voltages (VH$\sim$2V) were used as amplifiers.

The sensitivity of the apparatus was 4.10^{-15} A for 1 mm. of the galvanometer scale. Due to a specially selected procedure, the galvanometer deviations were proportional to the light flow, over the whole scale.

A vacuum oxygen-caesium photo element having a sensitivity of $30\mu A$/cm for a dark current of the order 8.10^{-13} Amps, prepared by the vacuum laboratory VEI, was used as the photo-element.

The stability of the circuit is expressed by a creep of 1-2 mm. on the scale of the galvanometer for a duration of 1-2 hours.

The optical part of the apparatus consisted of a monochromator with a slit width from 0.1 to 0.2 mm. The schematic of the apparatus is shown on Fig. 3.

4. The Results of the Polarization Measurement and Their Interpretation.

Simultaneously with the other measurements, a determination of the degree of polarization of light scattered by the fog at angles of 60, 90 and 120° was carried out. The measurements were carried out visually with the aid of a Cornu polarimeter (A ..llaston prism gives two images of the square of the entry opening to the instrument; with the aid of a Nicol prism, the brightness of the two images is equalized, the position of the Nicol prism determines the degree of polarization).

We find it expedient to begin the presentation of results with these data on polarization, in spite of the fact that they are less complete.

One of the typical curves obtained is shown on Fig. 4. The curve has a maximum at the small, instead of the large, angles of scattering. This demands a special analysis.

[illegible] (Rayleigh) scattering [illegible] shown on Fig. 5. [illegible] particles become very [illegible] compared with the wave length of the light, then, as is known from Mie theory the symmetry of the polarization curve for scattered light is dis[illegible]. A polarization curve for the case, when the radius of the scattering particles is r = 0.10μ (for green light λ = [illegible] mμ), is shown on Fig. 6. The maximum of the polarization is displaced in the direction of the large angles of scattering. For r = 0.13 μ a further change in the curve takes place (Fig. 7). The polarization for the scattering angle φ = 90° becomes smaller as r increases. The values of the degree of polarization for φ = 90° at various values of r are compiled on Fig. 8.

Fig. 4 shows that a reverse direction for the course of the curves can be observed in a fog. This can be explained if we consider that the light, scattered by the fog is composed of two parts: the Rayleigh scattering and the scattering due to large drops according to Mie.

We will first make general remarks on this phenomenon. It is known, that for the scattering according to the Mie theory not only the elongation of the polarization curves in the direction of the larger values of φ (Fig. 6 and 7), but also the analogous elongation of the indicatrix of the

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scattering ar[illegible]. The scattering takes place mainly in the direction of the large ψ and forward. But the Rayleigh scattering has a symmetrical indicatrix. If in a fog we have two types of particles, one of which scatters according to Rayleigh, and the other according to Mie, then the relative share of the two components will depend on ψ. If I_m (120) is the intensity of scattering by Mie at $\psi = 120°$, and I_m (60) is at $\psi = 60°$, and for the Rayleigh scattering the corresponding components will be I_r (120) and I_r (60), then from the above it follows that $I_m (120) > I_m (60)$, and at the same time $I_r (120) = I_r (60)$. If both types of scattering act simultaneously, then the total intensities will be: $I (120) = I_m + I_r (120)$ and $I (60) = I_m (60) + I_r (60)$. The share of the Rayleigh scattering for both cases will be

$$y(120) = \frac{I_r (120)}{I (120)}$$

and

$$y(60) = \frac{I_r (60)}{I (60)}.$$

It is apparent that $y(60) > y(120)$. But the Rayleigh scattering is more strongly polarized than the scattering according to Mie, hence it is natural to expect that the greater $y(\psi)$, the greater will be the degree of polarization of the scattered light for a given ψ.

From this point of view, curves of the type shown on Fig. 4 present proof that the Rayleigh scattering is noticeably present in the total scattering of light by fogs. The question

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[illegible] this scattering appears to us to have special significance, and, therefore, we will analyze it in more detail.

[illegible] The [illegible] of the Theory for the Transition of Light Through Fogs.

For further interpretation of our results, it is necessary to discuss the existing ideas on the mechanism of the reduction of light by fogs.

Disregarding the question of the selective absorption, the known theory by Stratton and Houghton gives a law characterizing the basic factor of the reduction in light: dispersion (from now on we will consider the regions of visible and infra-red spectra up to $\lambda = 1\mu$ for which our measurements are taken). The scattering coefficient according to Stratton and Houghton is equal to $k = 2\pi nr^2 k$, where n is the number of the drops of radius r in 1 $cm.^3$ of fog, and k is a function of r and λ, shown on Fig. 9, where along the abscissa $x = \frac{2\pi r}{\lambda}$ are plotted. At a given r this curve determines the spectral course of the fog transparency, by changing r, the spectral course changes. The region of small $x (x < 4)$ corresponds to the Rayleigh scattering, and the region of large $x (x > 14)$ gives the neutrality of the fog and even a decrease in the transparency in the direction of the infra-red rays.

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Considering the region of the spectrum 400 $m\mu \leq \lambda \leq$ 1000 $m\mu$, we have for x = 14 the condition $0.9\mu \leq r \leq 2.2\mu$. Therefore, for a fog, the drops of which have a radius larger than 2.2μ, we must expect neutral transparency and even some decrease in transparency in the direction of large λ.

Does this correspond to reality? To this question we must give a negative reply. Going somewhat ahead of the story, we will cite some data on transparency, obtained by us.

A curve of fog transparency measured by the photo-electric apparatus Oct. 4, 1940, is shown on Fig. 10 (curve 1). The time of measurement was 5.45 a.m. The transparency noticeably increases in the direction of the larger λ. On Fig. 11 are shown the radii of the drops measured at at the same time (5.40 a.m.). The predominating dimensions of the drops are $r = 1.7\mu$. If on the basis of the distribution of the radii, we calculate the theoretical course of the transparency by Stratton and Houghton, we obtain curve 2 of Fig. 10. (It is hardly necessary to point out that in the presence of drops of various dimensions in a fog, the substitution in the Stratton and Houghton formula is connected with the necessity for calculating the individual radii and with a consecutive summation, called for in similar cases).

A comparison of the theoretical and experimental curves clearly illustrates an essential discrepancy.

Such discrepancies are not the exception but the rule. Most of the data existing in literature shows that quite frequently we can observe an increase in transparency in the direction of larger λ at sufficiently large r (up to and exceeding 10 μ).

Since the time of publication of the Stratton and Houghton theory (1931) there were no works introducing anything new into the explanation of this problem. Nothing more was added than more exact mathematical calculations, although sometimes these were very essential by themselves. Occasionally indications are encountered that the theory of Stratton and Houghton is a rough approximation. It is doubtful whether such assumptions have a serious basis. The limitations introduced by the authors into the original assumptions of their theory have a completely definite meaning, the elimination of these limitations can only give more precise results, but cannot change the basic reasoning (particularly, in relation to the fact that starting from a drop of a known radius the scattering becomes practically neutral). The improvement of the existing theory for the transfer of light through fogs consists according to our point of view, not in the improvement of the Stratton and Houghton theory (in any case this approach cannot be the basic), but by finding new physical factors which essentially affect the course of this phenomenon.

Often, the observed deviations beteen theory and actual measurements are so great that no agreement is possible without a definite change in the basic concepts.

It appears that from this point of view particular attention is demanded by the problem, which was encountered in the discussion of the results on the polarization measurements - the question on the presence of carriers of the Rayleigh scatterers of light in a fog consisting of large drops.

6. The Hypothesis of the "Submicroscopic" Particles in a Fog.

We will assume that in a fog, in addition to the drops measured by photomicrography, on the basis of which the calculations are always carried out by substituting the value for the radii in the Stratton and Houghton formula, there are also drops whose dimensions are so small that they are invisible under the microscope. These two types of particles we will for brevity name "microscopic" and "submicroscopic". The assumption that such "submicroscopic" particles are present in a fog is quite plausible from the point of view of general physics. Their presence will essentially show itself in the optical properties of a fog. We will first analyse the share of the submicroscopic particles in the total scattering of light by a fog.

For microscopic particles the light energy dispersed by one drop, as is known, is proportional to the square of its radius. We will assume that in addition to the large particles of radius r_1 there are also present in a fog small particles of radius r_2. We will designate the number of these particles in 1 cc. by n_1 and n_2. The total scattering coefficient will, therefore, be proportional to the sum $n_1r^2 + n_2r_2^2$, and the share of the scattering due to the small particles by comparison with the large will be determined by the ratio $Z = \frac{n_2r_2^2}{n_1r_1^2}$.

The relation of the mass concentrations will be determined from the fraction $\sigma = \frac{n_2r_2^3}{n_1r_1^3}$, from here $Z = \sigma \frac{r_1}{r_2}$.

For clearances we will calculate one numerical example. Let $Z = 1$, $r_1 = 6\mu$, $r_2 = 0.3\mu$. We find that $\sigma = Z\frac{r_2}{r_1} = 0.05$.

This means that the small particles will bring about the same scattering of light as the large, if their mass concentration constitutes only 5% of the total. Quite small quantities of water, when they appear in the form of small drops, produce a very large optical effect.

Carrying out similar calculations it must be remembered that for particles which are very small compared with the wave length of light ($r \ll \lambda$), the dependence on the radius will be different: according to the Rayleigh formula, the intensity of scattering is inversely proportional to the square of the volume.

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In this case $Z = \frac{n_2 r_2^6}{n_1 r_1^6}$, from here $Z = \frac{r_1^3}{r_2^3}$. In other words, at a given mass concentration of drops, the particles for which $r \ll \lambda$, scatter proportionally to the cube of their radius, but for large drops the scattering is inversely proportional to the radius. At what dimensions of the particles does one law transform into the other? Turning to the theory of Mie we become convinced that such a transition takes place when r is of the order of 0.1μ, if we take into consideration the scattering of visible radiation. A polarization curve calculated by the Mie theory is shown on Fig. 8. This curve shows that the Rayleigh law for scattering does not hold for values of $r > 0.1\mu$.

However, it must be remembered, that the Mie calculations relate to colloidal solutions of metals. For water the optical constants have different values, but the order of the magnitude for the transition values of the radius remains the same. From the curve by Strattion and Houghton (Fig. 9) we observe that the region $x < 4$ is the region of the Rayleigh scattering. From the equation $x = \frac{2\pi r}{\lambda}$, assuming $\lambda = 500\ m\mu$ and $x < 4$, we obtain $r < 0.3\mu$. Thus, drops of radii several tenths of a micron appear to be the transitional drops from the Rayleigh scattering to the Mie scattering.

Fig. 12 illustrates these relations. The curve gives the value of the scattering coefficient (in the usual units) per unit mass of water, in relation to the radius of the drops, through which the unit of mass in the fog is expressed. It is exactly in the region of the radii which are too small to be observed by the usual microscope that the scattering coefficient reaches particularly large values.

For the optics of a fog, it is particularly important that the submicroscopic particles, which scatter according to the Rayleigh law (or "Quasi-Rayleigh", i.e., the dispersion coefficient is proportional to λ^{-t} where $t > 1$: this is the transition region on the Stratton and Houghton curve), increase the transparency of fogs for infra-red rays comparatively with the transparency for visible rays.

The particular importance of this condition, as follows from the earlier statement, arises from the fact that if by a direct measurement in one or the other case it has been established that the drops in a fog have an $r > 2.2\mu$, and that under these conditions the transparency increases in the direction of larger λ, then each such case becomes unexplainable from the point of view of the Stratton and Houghton theory. But it is precisely such cases that appear to be typical for fogs. As one example out of many, we will cite the curves obtained from the measurement of fogs on the Mt. Elbrus carried out by the Optical State Institute

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in 1934 (Bokin, Brumberg, Lebedev, Cherniav). Two curves for the transparency are shown on Fig. 13. Both curves are of a fog having large and almost uniform drops (r= 8 and 9μ), but the spectral course of the transparency is different. Moreover at such large values of r, the increase in the transparency in the direction of larger λ cannot be in agreement with the Stratton and Houghton theory.

On the contrary, if we take into account the part of the submicroscopic particles, then the increase in transparency in the direction of larger λ becomes understandable. The example shown on Fig. 14 explains this problem from a quantitative point of view. We calculated the theoretical absorption coefficient for the wave lengths from 400 to 1000 mμ for four types of fogs:

1. Monodispersing fog, r = 5μ. Calculated by Stratton and Houghton (curve 1).
2. The same fog but containing 1% (mass concentration) of drops r = 0.2μ (curve 2). The calculations are based on the curve of Fig. 12 assuming that the submicroscopic drops scatter according to the Rayleigh law (the scattering coefficient $\sim \lambda^{-4}$).
3. The same fog, but the mass concentration of submicroscopic drops equals 3% (curve 3).
4. The same fog but with a mass concentration of submicroscopic drops of 6% (curve 4).

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[illegible] the curve the absorption coefficient for $\lambda = 1\mu$ is considerably [illegible] as 1.

[illegible] clearly illustrate the great effect that submicroscopic particles exert on the transparency of fogs.

How can the hypothesis for the submicroscopic particles be directly checked? Some of the results of our initial investigations in this direction can be cited.

The polarization curves (Fig. 4) observed by us can be explained, as was pointed out in 4, from the point of view of the hypothesis of submicroscopic particles. During the field observations in September-October, 1940 we were able to establish that the shape of these curves changes from fog to fog, as well as with time for any given fog. This can be easily explained, since the number and dimensions of the submicroscopic particles in a fog undoubtedly change with time. Therefore, one can expect simultaneous changes in the spectral transparency of a fog.

On the 14th of October, 1940, we succeeded in carrying out a series of simultaneous observations for polarization and transparency. The transparency was measured by the photoelectric method. The optical properties of the fog were changing with time, and we succeeded in establishing a parallelism in the changes of transparency and polarization. It was found, that with time the shape of the polarization curve was changing in such a way that, from the point of view

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of the hypothesis on submicroscopic particles, it was necessary to assume an increase in the Rayleigh scattering of light. Therefore, an increase in the relative transparency of a fog for long wave radiation could be expected, which in reality proved to be the case.

This type of agreement in the polarized spectrophotometric measurements is the more essential, since the simultaneously carried out measurements on the drops showed that it is impossible to harmonize the results of the transparency measurements with the Stratton and Houghton theory.

The compilation of a similar series of observations will be our specific problem for future work.

7. The Results of Measurements of the Absorption of Light by Fog.

We have obtained measurements for several dozen curves of the spectral transparency of natural fogs by the methods described in (2) (with the aid of a spectrograph and a photoelectric apparatus using a monochromator). We will analyze a few of those.

First we will describe the fog which has occurred in the evening on the 21st September, 1940. This fog deserves attention from the point of view of the Stratton and Houghton theory, since it was isodispersing to a high degree.

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[illegible] radii is [illegible] a theoretical absorption [illegible] Stratton and Houghton [illegible]. A comparison [illegible] results (Fig. 16) [illegible] the curves for λ = 610 $m\mu$, n = 1 is assumed). In order to explain the curve, it is necessary to assume that the fog contained 1% of submicroscopic drops of a radius 0.2 --0.4μ. Even a more significant discrepancy is observed with the curve measured by the spectrograph Oct. 4, 1946. (It must be noted, that due to small dispersion and wide slits the monochromator in the photoelectric apparatus, its chromatic resolving power is small: 10--20 $m\mu$ for the visible region. Due to this we could not obtain smooth curves, which must be taken into account when comparing this data with the data of the spectrograph).

The variation in the transparency of the fog for infra-red rays is well illustrated in the curves measured by the photoelectric apparatus 4th and 5th of October. These curves are shown on figures 17 and 18. We will first analyze the curves of October 4th. Fig. 17 shows average (typical) curves for the given time intervals. (Nine curves were obtained during this time, all of them are not shown due to lack of space). All curves show an undeviated increase in the transparency in the direction of larger λ. They all contradict the results of the Stratton and Houghton theory. We have already shown the distribution of drops according to their radii for this fog (Fig. 11) and the calculated theoretical curve (Fig. 10). It must be noted that the contradiction with the mentioned theory is of a double nature:

1. the spectral course of the transparency is quite remote from the theoretical.
2. the spectral course of the transparency changes with time, at the same time as the dimensions of the drops measured by a microscope remained practically unchanged.

As has already been pointed out, both these factors can be explained by the presence of submicroscopic particles, the number of which, as follows from the polarization measurements was also changing with time.

The transparency curves measured on the 5th of October give an analogous picture (Fig. 18). From the curves it is possible to trace the dynamics of the change in the optical properties of a fog with time. It is evident, that as the fog begins to disperse, it becomes more and more neutral. This means that in this case in the dispersion of a fog the submicroscopic drops are the first to evaporate.

Although the hypothesis of submicroscopic particles gives an explanation for a large number of phenomena characterizing the transparency of fogs, there are, undoubtedly, specific phenomena observed in a number of cases the explanation of which does not fit into the framework of the present theoretical schemes. To these first of all belong the [illegible] selective absorption. In the infra-red region of the spectrum selective absorption can be noticed on the previously cited curves in the region 850-900 mμ (Fig. 17 and 18). For a number of cases absorption can be revealed in the region of 650-700 mμ. Particular attention from this point of view, is demanded by the selective absorption, revealed in the visible section of the spectrum by the spectrographic measurements. Fig. 19 shows several transparency curves obtained on the 20th of October, 1940, which reveal a sharply expressed selective absorption in the region of 600 mμ. This fog (more accurately haze, i.e. the visibility was greater than 1 km.) lasted for several successive days and nights. On the 21st of October we again observed on the transparency curves the selective absorption in the same region of the spectrum (Fig. 20). At present it is not possible to give a theoretical explanation for this type of curves. Thus on the 4th of October according to the spectro-photographic data even a more intense region of absorption was observed in the same section of the visible spectra, as shown on the curve of Fig. 21. Fig. 21 gives a theoretical curve according to Stratton and Houghton constructed by the measured photomicrographic distribution of drops according to their radii.

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We will note, that in this case the region of the spectra and the radii of the drops correspond to the section x from 10-15, i.e. to the region having a more clearly expressed selectivity, on the Stratton and Houghton curve (Fig. 9). None the less, due to the small value of the total absorption in this fog on the theoretical transparency curve shown on Fig. 21, no noticeable extremes are revealed. The observed selective absorption exceeds in magnitude the limit which can be explained by the Stratton and Houghton theory.

An attempt to give a general theoretical analysis of the possible causes for the selective absorption will be made in a separate work.

The fog of October 4th, in distinction to the one of the 20-21 of October, was of a comparatively short duration: it appeared around 5 o'clock in the morning, and by 9 o'clock it was completely dispersed. The fog which appeared the following morning (also a radiation fog, like that of Oct.4) did not have any selective absorption in the visible spectrum, as is evident from the transparency curves Fig. 22.

It must be noted that the transparency curves on Figs. 19-22 are shown in the usual units: for each day the largest measured transparency is taken as 1. Thus these curves do not give absolute values for transparency but the change in transparency according to the spectrum.

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Summing up the results of the first year of work on the study of the optical and physical properties of fogs, we must point out that we consider the basic conclusion is the necessity to take into account the submicroscopic drops in a fog. This hypothesis, detailed experimental investigation of which will be the subject for our work, is essential in order to understand the observed spectral laws. We have shown, that in the majority of cases it is not possible to give even an approximate explanation for the factual transparency of natural fogs for visible and infra-red rays, if we limit ourselves to the Stratton and Houghton theory. As shown by numerous data, the majority of natural fogs are composed of large drops ($r > 2.2\mu$): if we take into account, as has always been done up to now, only those drops which can be observed by photomicrographic methods we cannot explain the actual gain of infra-red rays in relation to the visible, from the point of view of better transparency which so often occurs in reality. Such a state of affairs cannot be considered satisfactory either from a theoretical point of view or from a practical attitude towards the investigation of fogs. The existence of submicroscopic drops in natural fogs opens up important perspectives. The of polarization measurements carried out simultaneously with the spectrophotometric measurements for the transparency presents great possibilities for the solution of this problem.

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In conclusion we wish to express gratitude to E. P. Smirnov for placing at our disposal the materials for submicrophotgraphic measurements on the structure of fogs which were widely utilized in this work.

Institute of Theoretical Geo-physics, Academy of Sciences. U.S.S.R.

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Translated by E. Rabkin

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N.R.C.

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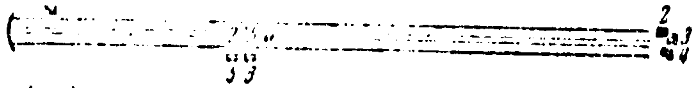


Fig. 1

The schematic of the position for the instruments: 1 - polarimeter; 2 - the direct vision spectrograph; 3 - the spectrograph, f: 4.5; 4 - the photoelectric apparatus with monochromator; 5 - the apparatus for the observation of the fog composition; 6 - the apparatus for the measurement of the fog moisture

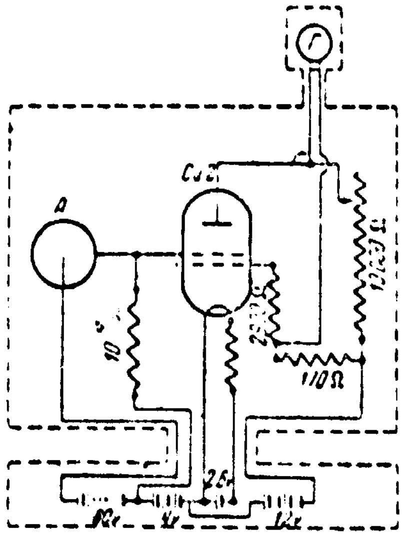


Fig. 2

The schematic of the amplifier for the photo current:
A - photoelement Г - galvanometer 2.10^{-9} A/mm.

27x10

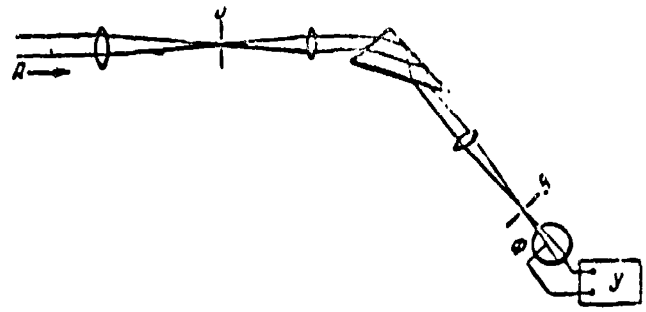
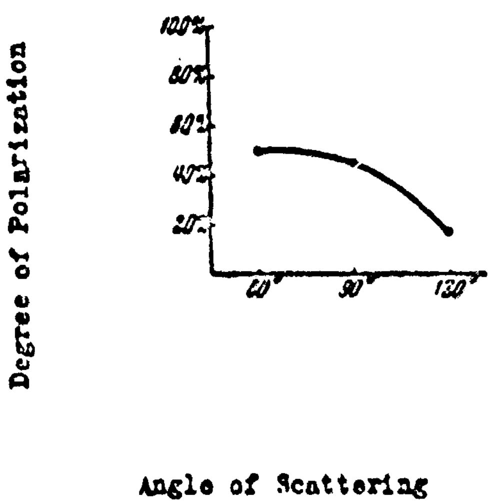


Fig. 3

The optical part of the photoelectric installation: A - the ray from the projector, Б - the entry slit of the monochromator ф - photoelement, Y - amplifier



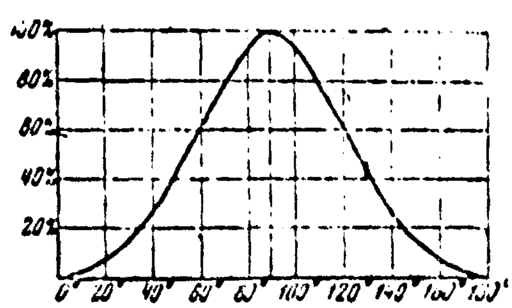


Fig. 4

The fog of Octobe. 14, 1940. 4 hours, 50 min - 5 hours, 10 min.

Fig. 5

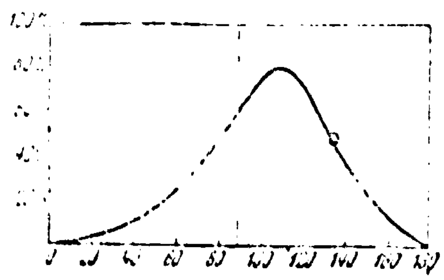


Fig. 6

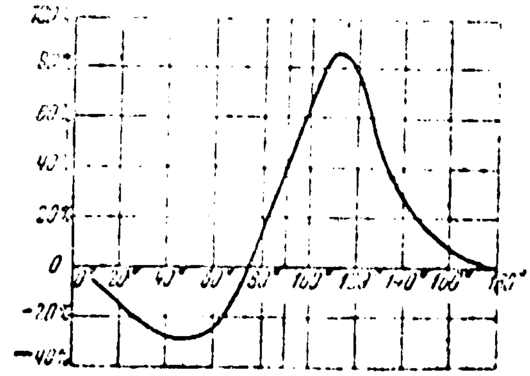


Fig. 7

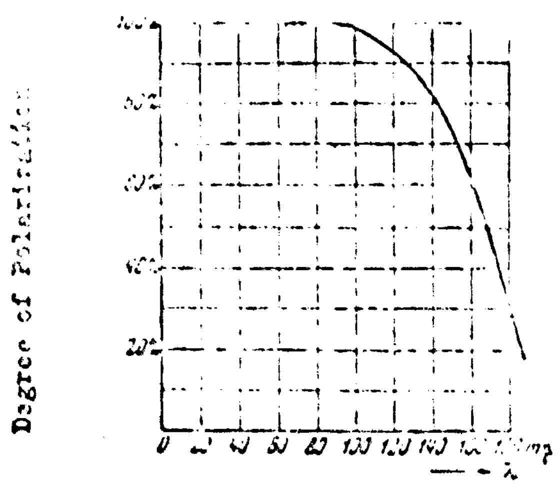


Fig. 8

31 ~10

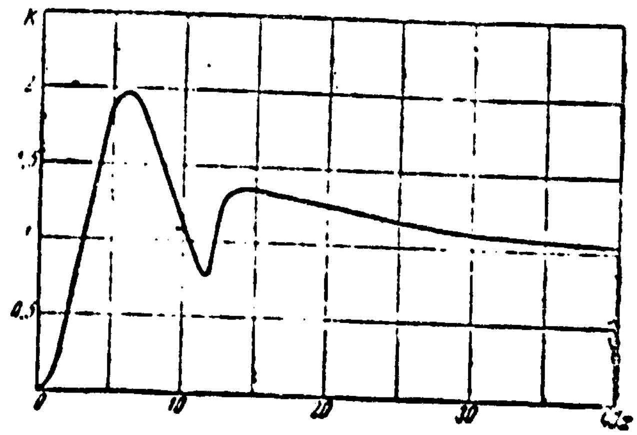


Fig. 9

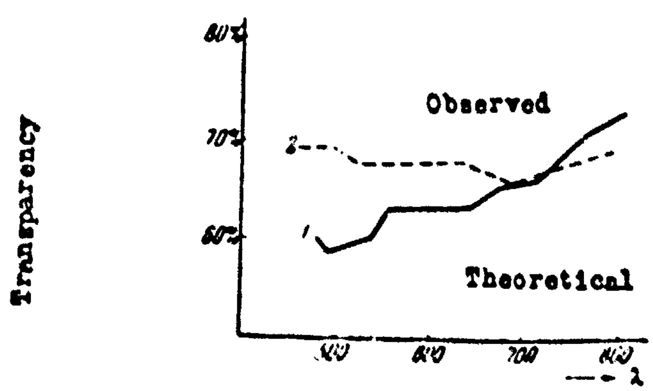


Fig. 10

Fog. October 4, 1940, 5 hours, 45 min.

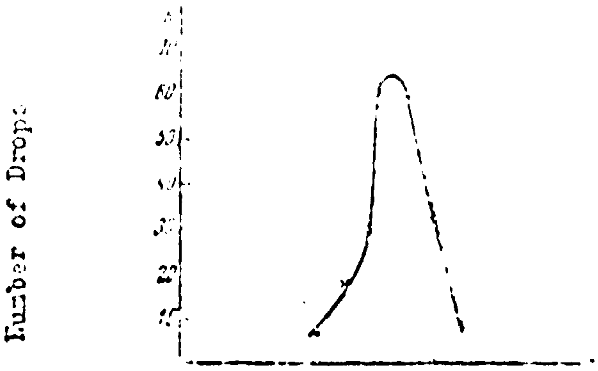


Fig. 11

Fog October 4, 1940, 5 hours, 40 min.

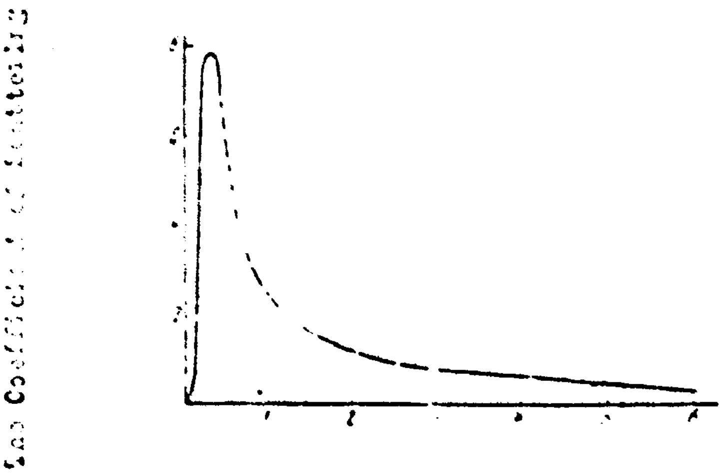


Fig. 12

33 ~10

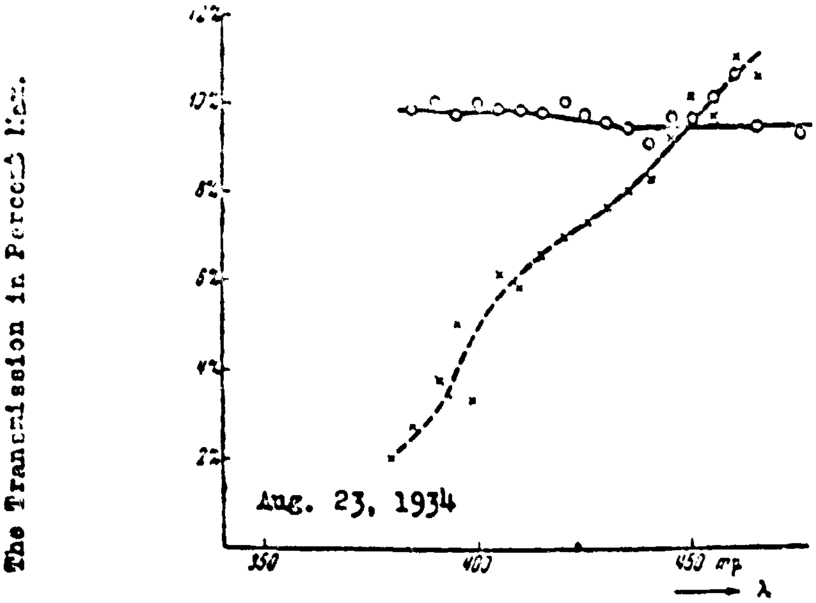


Fig. 13

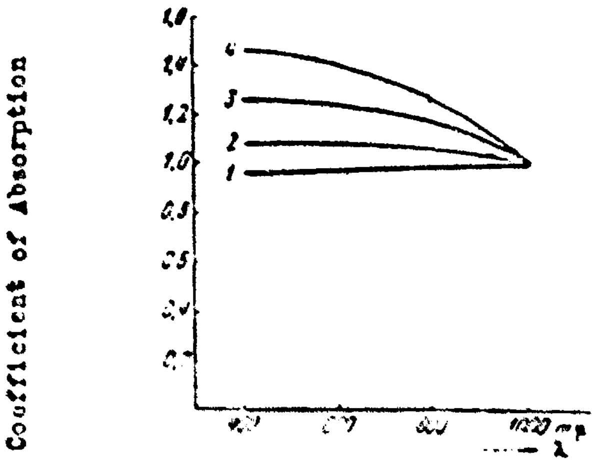
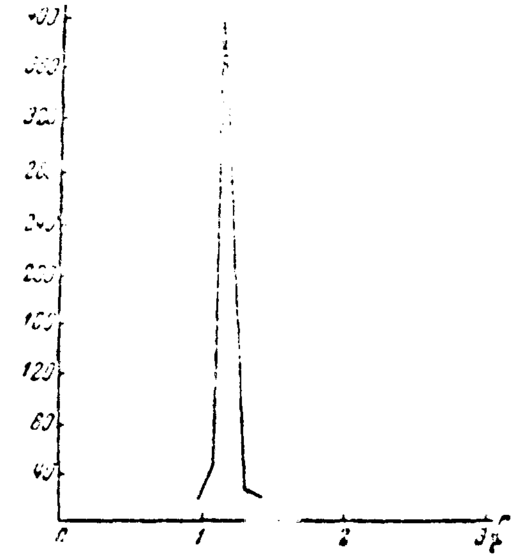


Fig. 14

34 n 10



The Radius of a drop

Fig. 15

Fog of the 21st Sept., 1940

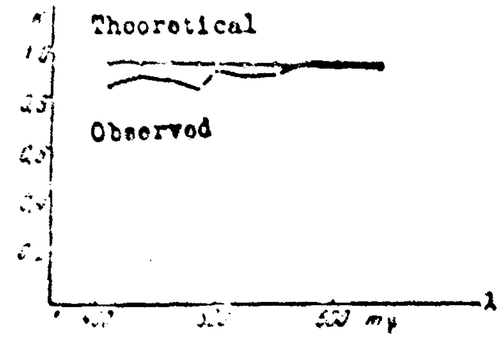
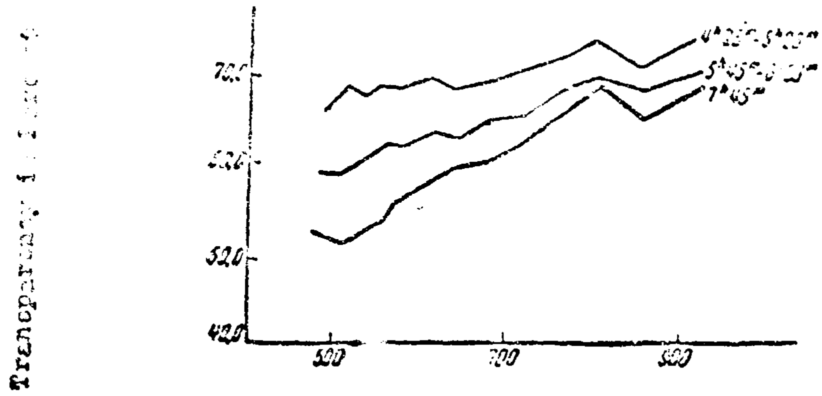


Fig. 16

Fog of the 21st Sept., 1940. 23 hours, 40 min.

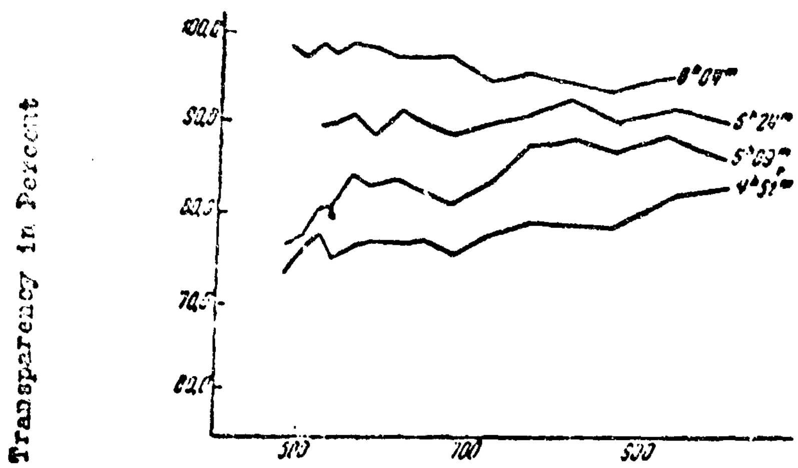
35



Wave Length in m μ

Fig. 17

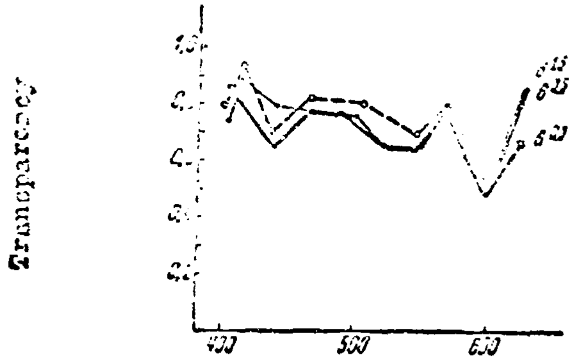
Fog of October 4, 1940



Wave Length in m μ

Fig. 18

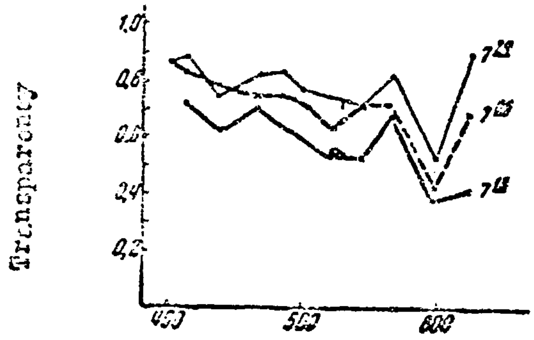
Fog of October 5, 1940



Wave Length in m μ

Fig. 19

Fog. (haze) 20th Oct., 1940



Wave Length in m μ

Fig. 20

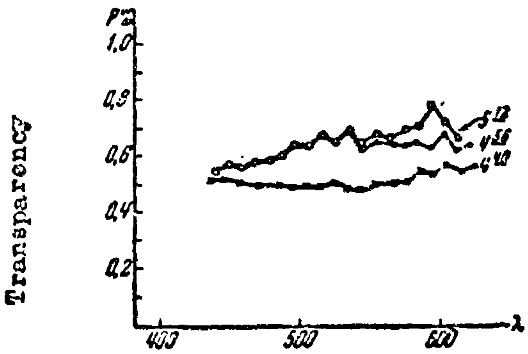
Fog. (haze) 21st Oct., 1940

Theoretical

Wave Length in m μ

Fig. 21

Fog. Oct. 4, 1940



Wave Length in m μ

Fig. 22

Fog. Oct. 5, 1940

37x10